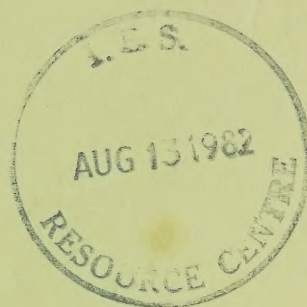


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SCIENCE FOR PUBLIC POLICY:

Highlights of Adaptive Environmental Assessment and Management

C.S. Holling

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SCIENCE FOR PUBLIC POLICY:
HIGHLIGHTS OF
ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT

BY

C.S. HOLLING

It all started with GIRLS. That was the acronym chosen for the Gulf Island Recreational Land Simulation study. GIRLS was an exercise to explore ways to bridge gaps between disciplines and between subject-matter experts and policy designers. It was the first step in a sequence that has since led to the concepts, methods and procedures of adaptive environmental assessment and management (AEAM).

Its essential purpose is to provide a flexible, adaptive approach to environmental planning, assessment, and management. Its methods draw upon a variety of modelling techniques to capture the essential biophysical and economic interactions, on policy analytic techniques to generate alternative policies, and on decision techniques to evaluate policy consequences. Its procedures emphasize a sequence of interactive workshops whose purpose is to combine the strengths of expert, manager and policy person so that relevant knowledge is focused on policy questions leading to adaptive decision making. The approach has been described in detail¹ and in summary form² elsewhere. Here I will concentrate on the dilemmas, complexities, and issues that arise in the development and application of such an approach.

It began in 1968 when it seemed opportune to capitalize on two trends. "First, there was a growing realization that a new class of resource and environmental problems was appearing, as exponentiating demand stretched the resilience of resource and environmental systems. Second, with the development of computers and modelling techniques, new approaches and methods had been developed to handle complex systems with many variables. For the first time, therefore, it seemed possible to design new research and policy strategies for those situations having large numbers of interacting components.

In order to capitalize on this historical juncture, however, it was essential to recognize that the history of the resource sciences had been moving very much in the opposite direction. Each of the disciplines — resource economics, ecology, geophysics, agriculture, fisheries, wildlife biology — had been developing overlapping but often independent methods and concepts. In addition, related forces had led to a growing separa-

tion between institutions, so that gaps developed in the logical flow of activities from basic research to applied, to design and pilot studies and to policy formulation and implementation. Wherever we looked, therefore, it seemed that there were gaps between methods, between disciplines, between institutions and between constituencies. The gaps in this sequence of activities, shown in Figure 1, seemed sufficiently embedded in the history of resource science to demand a carefully organized series of steps that could progressively bridge the gaps."

Most of those gaps were bridged, to some significant degree at least. But others have appeared. It is the purpose of this paper to review the highlights and to identify the new problems and gaps that have emerged. In short: what we learned and where we are stumbling.

WHAT WE LEARNED

The paragraphs in quotes and the figure below were composed in 1968. They still seem to be an adequate description of the status at that time. But our experience since then suggests three critical additions. First the gaps in the sequence of activities are obviously matched by gaps between people — between expert, manager, decision advisor, decision maker, and citizen. Hence the challenge was not simply to better understand the interrelated behavior of fish or fowl or economies, or to develop wonderful methods of modelling and policy analysis. It was more to develop an understanding of people — hence the communication methods and workshop procedures of AEAM where the strengths of disciplinary experts, policy analysts, managers and decision makers are blended. The second addition is the two-way interaction between policy formation and implementation, in order to more directly emphasize the unpredictable nature of policy design and implementation and the need to evaluate and adapt to the inevitable unexpected. And finally, as indicated in the figure, several words needed to be added for emphasis: deduction added to simulation to emphasize that there are a variety of different kinds of models, not just simulation models, each with different strengths; adaptation added to policy formation to emphasize, again, the adaptive

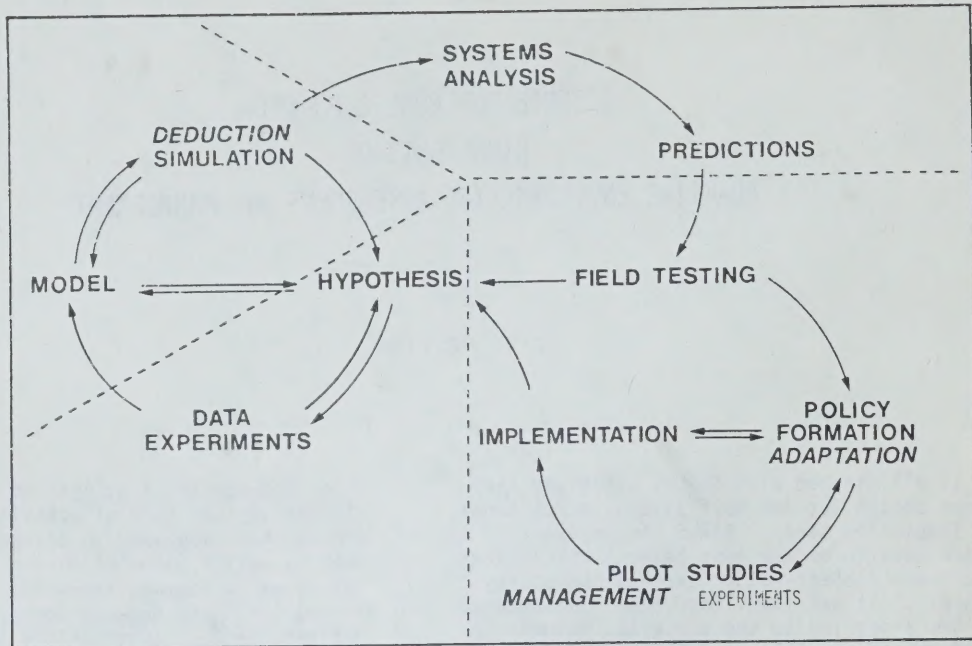


Figure 1: Sequence of activities required in analyzing resource systems and devising policies for management. The gaps inhibiting this progression are indicated by the broken lines.

nature of renewable resource assessment and management; management experimentation added to pilot studies to emphasize the active role of management design in probing and exploring the unknown.

Those additions lie at the heart of the adaptive approach. They represent aspects of the conceptual lessons learned. But concepts need to be matched with technique and technique has to emerge from practice. The highlights of the version of techniques that we evolved emerged from practical examples that, in retrospect, fell into three phases.

PHASE I: WHAT GIRLS TAUGHT US

1) Problem Entry

Any problem can be entered at various levels from very global to very micro. And yet the final results are largely determined by the entry point. More often than not, the entry point is dictated by one's own past experience. Hence, in a recent workshop exploring the consequences of alternative routes to transport oil from Alaska to the Puget Sound area, a wild fowl specialist argued that measures of wild fowl populations were the prime integrator of information concerning the state of environmental health of the marine ecosystem. A fisheries biologist, on the other hand, saw the world as one of catch/effort statistics and stock-recruitment relations in

which productivity would be impacted by oil spills. Both these views can be accommodated in the same analysis because they imply similar scales in space and time. Both require designation of alternative tanker routes, representation of spill probabilities, development of sub-models of oil movement, and estimates of population and animal movement by location and time of year. But a senior policy advisor of government argued that a larger scale analysis of energy supply and demand could well indicate that any transport of oil by tanker over new routes was unlikely because of likely changes in supply and demand. That represents a much larger geographical scale of analysis over a longer time horizon, but the end result could well alert the wildlife and fisheries biologists to issues and questions emerging in a radically different direction from their original inclination. Rather than simply reacting to proposed tanker routes that might never appear, they could, as well, anticipate developments and be part of their design.

It isn't that one scale of problem definition is correct and one wrong. In this example both are useful — the first in preparation for formal hearings concerning four specific proposals; the second in anticipation of the next round of issues just over the horizon. The point is that the scale of problem definition used should be an explicit decision based on needs, not upon one's own area of expertise.

Problems are defined not only by the scale in space and time but also by the choice of the processes most responsible for generating and responding to change. GIRLS is a case in point. The Gulf Islands, off the coast of British Columbia, have rare living resources on land and sea that have been progressively impacted by expanding demands for recreation and development. The first entry point, however, was not biological — it was economic and social for it was the forces of population growth, land acquisition and development that were the engines of change. That provided the opportunity, then, for biologists and others to evaluate alternative futures in terms of their primary interest and to explore alternative social and economic policies that could better protect or enhance those interests. That can set the stage to pinpoint second-order analyses where their special expertise can come into play. Subsequent to the GIRLS exercise, for example, the AEAM approach was used with fisheries biologists, economists, managers and policy people to develop radically new perceptions of impact of sport fishing on salmon and to develop new policies that are now being put into practice.

The prime lessons: one's own interest cannot blindly dictate the point of entry into a problem; whatever the point of entry there are contributions to be made to one's own interest; whatever the point of entry, it is useful to explore the consequences on larger and smaller scales.

2) Don't Start With Objectives — End With Them

Objectives of individuals or groups would seem to provide a logical way to start the analysis. A representative of a wildlife agency, for example, might express his objectives in terms of protection (of wildlife) or battle (vs. the developer). At times one objective can dominate the other so that in the drive to "get" the developer, for example, long term objectives relating to wildlife can be unconsciously compromised — winning a battle and losing the war. That problem of conflicting and hidden objectives within and between organizations presents the first problem. We encountered that early in the GIRLS project and found that the effort to define alternative objectives at the beginning was divisive and unproductive. We resolved the impasse by insisting that any early discussion of objectives be limited to defining both policy actions and evaluation indicators. Actions are those management or regulatory "levers" that can be applied using rules that define a policy. For example a simple fisheries policy might be to control fishing using actions such as limiting the size, bag, season or area in accordance to a rule that maintains a fixed number of spawning fish. Indicators are those quantities that in various combinations can define an objective. Indicators such as population density, productivity, income and catch can then be used to evaluate the ability of a policy to achieve different objectives such as maximizing sustained yield or economic return, minimizing income variability, or enhancing social equity. People can fruitfully define sets of actions and evaluation indicators knowing that at the end of the analysis alternative policies can thus be explored to meet their objectives.

The second problem in starting with a firm definition of objectives arises from the assumption that people know their objectives. But all our experience, and indeed that of pollsters of political elections, indicates that objectives emerge as an act of dialogue and growing understanding. The analyses and procedures should have that as their end-point, not their beginning. We have found this point of view to be particularly difficult for people from agencies with single missions to accept. And most difficult for those far from the scene of the problem. After all, if you are in headquarters, what else can you do to control your local personnel than to insist they define their objectives and stick to them? The result is the articulation either of fervent dogma or of counterproductive trivia.

The prime lessons: the identification of actions and indicators at the first gives policy direction to an analysis and limits the area of conflict; starting with objectives generates irrelevant conflict and minimizes learning; objectives are as much a part of the research and learning experience as is the development of understanding and policies.

3) A Model is not an Analysis

The GIRLS model and other similar simulation models represent an effort to develop a kind of laboratory world that can be used to integrate existing knowledge and identify gaps, to respond to questions, and to adjudicate conflict. There has been enough written in various fields that I will not dwell on their strengths (integration of parts to generate systems behavior, incorporation of non-linearities, and many variables) or weaknesses (danger of becoming too large, too detailed, too complex and unrelated to the questions). But a model is only effective if it is embedded in a larger process of analysis — problem identification, modelling, policy design and evaluation, and policy decision and implementation. We learned from GIRLS that a simulation model can be a powerful device to blend the knowledge of different disciplines, to make invisible assumptions visible, and to provide an environment to ask questions. That can lead to priorities for filling key knowledge gaps and to the exploration of the systems effects of actions and policies. But that only emerges if it integrates with the other parts of the process. Hence we learned quickly that GIRLS had to be transparent, capable of easy modification as questions emerged, and able to produce graphical information of different levels of detail and generality. Later studies that brought in a wider range of actors and constituencies only confirmed that need.

Prime lesson: simulation models can be a powerful tool in the overall process of analysis, but only if the communication interfaces with the other parts of the process are fostered.

4) Methods of Analysis are Not Enough

We have conducted analyses that use only a limited array of quantitative methods, either because information or understanding was sparse and qualitative or because the problem was technically straightforward. But I cannot imagine an AEAM project that was not structured around one or a sequence of workshops. For at its heart, the problem of linking disciplinary knowledge, policy design and evaluation is a problem of linking people — experts, managers, policy designers, decision makers, and constituencies.

The major barrier to AEAM is the scarcity of staff who have rigorous disciplinary experience and analytic and modelling skills combined with experience in dealing sensitively and constructively with people. But perhaps that combination of talents lies latent in more people than traditions would indicate. Certainly that is our experience in training individuals and teams from the U.S. Fish and Wildlife Service, Canada Department of the Environment, and within our university's graduate school. I present a graduate course in modelling methods and workshop procedures, for example, in which typically four or five individuals emerge with that combination of skills out of a class of 15 to 20. They must start with a strong disciplinary background and analytic skills. What is needed is a forum to tune, apply and expand those skills, and to match them with people skills.

Those procedures were first developed in the GIRLS workshop³ and refined, expanded and modified in subsequent ones.^{4 5} They dealt with ways to capitalize on and, at times, generate rhythms of frustration and advance, how to organize and not organize, how to deal with conflicts of principle, dogma and detail, when and how to be interdisciplinary, when and how to concentrate on disciplinary knowledge, and how to enrich and focus methods of communication and interaction. These procedures have been used in Austria, Canada, South America, the United Kingdom, and the United States. Although the basic features remain the same, different cultures and nationalities require adaptation of the details. What remains universal is the roles that appear during a workshop: the Peerless Leader who with astonishing commitment and perception takes on leadership roles for the greater good; the Utopian, who dreams the impossible dream and yet provides visions that can be filtered to separate imaginative ideas from fantasy; the Blunt Scot, a rare individual whose bluntness and sincerity of purpose transcend the mischievous irresponsibility that most of us succumb to occasionally. And finally there is Snively Whiplash, who clearly detests the whole effort, wishes to destroy it, and for some reason stays on throughout. But he is invaluable, for he can provide a focus of hostility that can crystallize a group spirit that can then be turned to more constructive purpose. The greatest danger we have encountered is that Snively can become a convert, and if sufficiently narrow can initiate subsequent activities that subvert the essential need to be adaptive and flexible.

The prime lesson: people, procedures, communication, and orchestration have to be pursued as a creative, carefully designed activity that matches knowledge and methods.

PHASE II. SMALL IS BEAUTIFUL VS. BIG IS NECESSARY

That experience set the stage for experiments in organizing the AEAM approach. Carl Walters undertook a set of experiments designed to explore how small and focused the organization could be and how rapidly the first stages could be implemented. Mike Goldberg and I dared to organize an effort that was both interdisciplinary and inter-institutional, with the aim of providing an open access planning and information system for the Lower Mainland of British Columbia. That was IIPS, the Inter-Institutional Policy Simulation Study — not as entertaining an acronym as GIRLS, perhaps suggesting we were taking ourselves too seriously. Both experiments experienced failures as experiments should. Failures provide the opportunity for learning. But the first set was highly forgiving of error because the experiments were of small scale, were replicated and had a stated experimental purpose. In contrast, the second was large scale, was of necessity unreplicated, and had an operational purpose. Those are precisely the ingredients that are unforgiving of error.

That experience led to a particular kind of organization that was neither the traditional interdisciplinary team nor the "contracting-out" device. It led also to a refinement of procedures and methods that accelerated the process. The following specific lessons were learned.

1) Big is Not Beautiful

The experiments showed that a large, centralized interdisciplinary team effort was unnecessary. The IIPS project showed, moreover, that such efforts were excessively costly in organizational, financial and emotional overhead. That project was organized with initial formal commitment of several departments of the city, a regional planning department, and the university. Fear of the unknown and fear of unexpected political consequences was, however, clearly present at the beginning. Nevertheless, the first year proceeded admirably through a series of workshops, the conceptualization of the problem, the identification of component parts and initial analysis and modelling of those parts and of the interconnections between them. The regional planning department in particular made public the benefit it received. The fundamental pitfalls that emerged were typical of many of the early large scale efforts of systems analysis, and these have been well reviewed elsewhere.^{6 7 8} There was inevitable drifting of the component analysis from the initial policy purposes to more diffuse scientific or philosophical purposes. There was the endless debate that process was everything vs. product was everything, when both have to be inextricably linked.

But the basic lesson is that large scale interdisciplinary projects are unnecessarily costly and require excessive organization and control.

2) Moderately Small is Necessary

At the other end of the scale, small efforts involving experts of single disciplines can be equally ineffective, even when the purpose is narrow. A number of workshops were held focusing on aquatic ecosystem studies sponsored by the International Biological Program. Those were largely descriptive field programs and we experienced little success in introducing the notion, by example, of dynamic causation and systems behavior, or of the use of models to direct and be directed by data collection and analysis. The parochial aspect of single disciplines too often reinforces dogma, buries hidden assumptions deeper, and smothers the analysis in irrelevant detail. Counteracting forces are needed to emphasize the need to respond to specific questions, not to all questions, the need to identify gaps in understanding of data and the necessity to assess the significance of those gaps.

Mixes of disciplines can help provide the balance as the narrowness of one discipline encounters that of another. Moreover, the significance of interactions between parts of a system is forced into the open. But we found the optimum balance was provided by a mix including experts from several relevant disciplines, resource managers and policy people. The former keep the latter two honest. The latter keep the former relevant.

The prime lesson is that single disciplines can be blindly parochial and incestuous and that a blend of expert, manager and policy people can lead to a balanced interplay of strengths. There is a much enhanced chance that specific questions of importance will be addressed, that priorities for key information needs can be established and that fruitful and unexpected policies can be identified.

3) Organization Has to be Adaptive Too

Smallness can allow for regulated flexibility. Even problems of large scale and purpose can be structured as a set of smaller functions that can be interrelated with the minimum of organizational overhead. The organization we evolved by trial and error involves four groups:

● The "Project Team".

The project team is the client who has, typically, been charged by one institution to perform an assessment or to design and evaluate alternative policies concerning a resource and environmental problem. That problem in the past has been as narrow as management of a specific fisheries or wildlife population or as broad as a regional analysis of a major hydro-electric, or other development that has broad social, economic, environmental and resource consequences. In one

instance the problem was continental - albeit the sparsely occupied one of Antarctica.⁹ There is no reason why the problem could not be global (e.g. climatic change from CO₂ accumulation) except for the need to identify alternatives to the non-existent global decision-maker.

● The "Workshop Staff".

This is the group of four to six analysts who jointly have backgrounds in a number of different resource disciplines, are familiar with a spectrum of analytic modelling and policy techniques, and have the talents and experience to facilitate and guide groups of people in workshop and post-workshop settings.

● The "Core Planning Group".

This is made up of the leader of the "Project Team", perhaps one or two of his senior staff, and the workshop staff. Their responsibility is to plan and set the sequence of activities, to identify institutional opportunities and problems, and to identify key participants in various institutions - experts, managers and policy people. The Program Leader and Workshop Staff lead and guide the workshop(s), acting as a policy analytic staff for the "Participants".

● The "Participants".

The participants are the experts, managers and decision people, typically from a number of institutions, who have key roles to play in technical or decision aspects of the problem. They are the ones invited to the first workshop. It is their talents and experience that are orchestrated to produce a first cut model of the problem that is used to assign priorities for information and data needs, model development and policy analysis.

The sequence of activities starts with a scoping session of one or two days involving only the core Planning Group. The problem is explored in some detail in order to develop an initial bounding of the problem - actions, indicators, variables, spatial extent and resolution, time horizon and resolution. That is done only to the degree necessary to identify key participants and information needed for the first workshop. Responsibilities are assigned for collation and organization of existing information, for selection and invitation of participants and for organization of the workshop itself.

That first workshop follows within two months, and over five days operates in a rhythm that moves from establishing the policy framework (actions and indicators), to interdisciplinary identification of variables, space and time and the interconnections between them, to development of submodels by disciplinary groups, and finally to exploration of policy and information questions. The result is a set of priorities for information, for modelling, analysis and policy design, together with responsibilities to address those needs.

That typically is followed by a two to three month period of independent work leading to a second workshop with the same people to produce a refined analysis, model and policies, and priorities for subsequent steps. Again periods of independent work follow, paced and ordered by other workshops. Some of these are designed only for technical people in order to subject the work to criticism and to expose it to a larger technical audience who often have significant advisory roles in policy-making. Later workshops focus on a larger community of managers, decision makers, and citizens. Throughout, the rules are to make everything as transparent as possible, to provide an interactive environment, and to modify the analysis, models and evaluation as new questions and suggestions emerge.

The prime lessons: a small organization with the core tightly organized and the participants more loosely integrated can address not only simple but highly complex resource and environmental problems; a great multiplication effect occurs through the network of participants that reduces the central budget, accelerates communication, and provides an early warning of problems. Sanity, innovation, and learning are encouraged by the rhythm of intense short periods of interdisciplinary and policy analysis, interspersed with independent consolidation; the scheduling and focus of each workshop sets the deadlines and pace. And finally, every effort must be made to provide opportunities for self-discovery by all actors.

4) Connecting the Parts of a Model

Submodels are the parts of the full model. They are chosen to include variables which interact tightly, in a complex manner and at similar scales of space and time. The goal is to divide the problem into such submodels so that relatively little information needs to be communicated between them. Those interconnections are absolutely key, for from them come many of the unexpected policy effects as social, economic, resource, and biophysical aspects combine. They generate those surprises, crises and opportunities that challenge so much of resource and environmental management.

In every workshop some of the experts push to represent their submodel in exquisite detail. They are understandably motivated by scientific interests and not by policy ones. But that leads to a level of complexity and detail that typically prevents linkage of submodels. Carl Walters resolved that with the innovation of the "Looking-Outward Matrix". The notion is deceptively simple. Don't let the expert tell you what information he can provide. He cannot be expected to know what other experts or policy people need. Rather ask him what he needs from other experts' submodels. That leads to a matrix that identifies the variables and units needed by each submodel from others. Hence the interconnections between the parts are identified from the start. Reading the table one way identifies the inputs that a submodel will receive. Reading the other way identifies the outputs that others require. In addition, each sub-group knows the actions that

need to be incorporated and the indicators that have to be generated. The definition of inputs and actions and of outputs and indicators goes a remarkable distance in defining the contents and scale of each submodel. And it gives an overview of the structure of the system that, in some workshops, has been all that was required to better order and focus the research and policy effort.

Prime lessons: Many interdisciplinary and "contracting-out" modes of analysis defeat the policy purpose because the component parts of the studies can never be interconnected. The solution is not to ask the expert what he can do for you; ask him what he needs from others. The results are used to structure the constraints imposed on each component analysis so that they respond to the policy needs at a relevant level of detail.

PHASE III. THE PROOF OF THE PUDDING IS IN THE EATING

By 1974 we had developed effective ways to bridge gaps between disciplines, methods and concepts, between analysis and policy design and between expert, manager and policy person. Equally important, we had learned how not to bridge the gaps between institutions. Hence we entered a new stage of implementation. We wanted problems that contained immediate issues of major social, economic and environmental concern, within complex institutional settings. We wished to move the full range from analysis to decision. Four major projects evolved:

Forest/Pest Management — The pulp and paper industry and employment in New Brunswick, Canada had been maintained since the 1950s by an extensive insecticide spraying program. The target was the spruce budworm which periodically has destroyed most of the mature balsam of that province. The spraying program had reduced tree mortality but at a price: incipient outbreak conditions covering larger and larger areas, escalating costs, greater dependency on continued spraying, public opposition, and no easy or perceived options. Some 20 government agencies have some say in the matter and two key ones were at loggerheads — a federal agency responsible for research and a provincial agency responsible for management — with all the entwined personalities, grievances and territorial defence which that implies.¹⁰

Salmon Management and Enhancement — Salmon populations on the west coast of Canada are 50% of their original levels with the likelihood of collapses of major stocks only now being detected by public interests. Management of commercial and sports fishing faces the classic problems of mixed stocks, technology outstripping regulation, conflicting pressures from commercial, sports and environmental interests, divisions between research and operational agencies, and provincial, federal and international conflicts. A major investment into salmon enhancement facilities will produce more fish, with the potential of triggering the same sequence seen

for spruce budworm management. Increased enhanced populations will lead to increased harvest of all stocks, so that the less productive natural stocks will be driven to collapse. The industry can be left precariously dependent on a few enhanced stocks that are vulnerable to collapse.¹¹

Regional Development in an Alpine Region -- Obergurgl is a village in the Austrian Alps. Its population of 300 is inundated each year by some 40,000 tourists. Prior to 1950 the village lived a precarious and isolated existence based on high alpine farming -- so precarious that the community decided to ban marriages between 1830 and 1850. One hundred years later came the explosion of tourism, and now 70 hotels with associated ski lifts and hiking trails dominate the village. The problems are a microcosm of global and regional problems -- erosion and environmental degradation that threaten the new economic base, fear of too much demand, and of too little demand, rising expectations and conflict -- between have and have-nots (hoteliers and farmers), young and old. In 1975 the conflicts were deep and growing.

Problems of a Single Mission Agency -- Agencies with the single mission of protecting and managing fish and wildlife often lack extensive legislative and administrative powers. As a consequence, their personnel often view themselves as beleaguered defenders of cherished values that are under continual and successful attack. Continual erosion and destruction of those values seems inevitable. And externally, they are often viewed as a reactive and reactionary organization containing competing fiefdoms bound by traditions whose defence becomes of greater importance than does resource stewardship. In order to explore alternative ways for such agencies to deal with their special mission in a world of many missions and needs, a number of specific problems were chosen that typified such issues for the U.S. Fish and Wildlife Service. They included problems of water resource allocation both in the Truckee-Carson system of Nevada and in California, of animal damage control in the Pacific Northwest, and of acid rain impacts on fish. Each involved fish and wildlife interests, each intersected directly with other missions of other agencies, and each encountered conflicts with different constituencies.

Those four projects hence share the classic set of problems faced by most examples of resource and environmental management. But they also shared one other critical ingredient that determined their choice. Each had an individual within the system who became a critical partner in the endeavor. They were the professional implementors, and the university group were the amateurs. This group of four wise men were so central they shared with us the responsibilities for both the strengths and weaknesses of developments. They and others described the triumphs and frustrations of implementation in a policy seminar of the International Institute for Applied Systems Analysis (IIASA) held in June 1979.¹² And further events have transpired since then:

Budworm -- The federal research agency remains little changed but the operational agency (the Department of Natural Resources, New Brunswick) has changed its program of inventory and wood supply analysis and has instituted a policy and planning division covering all aspects of forest management under the direction of a new Assistant Deputy Minister -- our very own wise man, Gordon Baskerville.

Salmon -- The Salmonid Enhancement Program was a new, semi-autonomous entity that was committed, from the start, to the adaptive philosophy and approach. Policy, planning and operations are hence interwoven with those notions. The salmon management program was part of an existing line department that began to initiate a change in the management approach when, for other reasons, the strategic and most of the tactical level staff were lost in an organizational change in 1978. Now, however, a new group has begun to implement changes in fishing regulations triggered, in part, by AEAM.

Obergurgl -- The grand success story is Obergurgl. A critical town meeting was held in 1974 in which citizens and officials debated the issues with an interactive computer model as the mediator of questions and the core group as the facilitators. Farmers, hoteliers and scientists now claim that the model, analysis and interactive meeting turned growing polarization and conflict into collaboration. There has been no hotel construction since, and hoteliers have established funds to subsidize farming activity and further modelling and analysis to cope with future surprises. They argue that quite apart from specific decisions that followed, the most significant and profound result was that farmers now feel an honored and integral part of the village's future.

USFWS -- The effort to encourage change focused on the training of a workshop staff within the service. That was accomplished by having them do it -- run workshops, perform analysis, interact and orchestrate. If you are going to learn to swim you have to jump in the water. The projects chosen were hence guinea pigs, in part suffering by the learning experience, in part benefiting by it. Significant contributions were made to the Truckee-Carson River Quality Assessment Project in direct collaboration with the U.S. Geological Survey (USGS) and to the San Joaquin/Sacramento Rivers analysis in collaboration with the FWS California Water Policy Center. The group is now completely able to conduct workshops and post-workshop activities. Satellite groups have emerged elsewhere. Whereas once our phone was frequently ringing with requests for assistance, now we have to phone to discover their continuing triumphs and frustrations.

Only when the pudding is eaten are the ingredients tested. Hence these final lessons are central to changes sought for in the management and protection of renewable resources. A senior administrator and policy advisor in govern-

ment summarized his problem as follows. "Scientists keep telling me what a bunch of dolts bureaucrats are, and bureaucrats keep telling me what a bunch of nerts scientists are." And methodologies damn and are damned by both. How do we select and combine knowledge, methods and institutions for a policy purpose?

The critical problems and lessons are as follows:

1. Science

The workshop procedures and the qualitative and quantitative methods provide an effective way for the scientists and experts involved to develop a coherent expression of their understanding and coherent advice to the manager and administrator. Alternative policies emerge that are qualitatively different from those previously devised and an effective range of comprehensible choice is provided for decision. But as well, we discovered that the quality of the science itself was radically improved. That new discovery emerged because implementation demands that which is simple, clear and relevant. Above all, science seeks for understanding. And simplicity is the hallmark of understanding.

2. Methods.

Much of the theory and methodological developments took place in collaboration with outstanding analysts at IIASA — with Dantzig of optimization fame, Raiffa of decision theory, and Koopmans of economics. The revolution in our thinking concerning concepts and methods was triggered by them and is discussed in detail elsewhere.¹³

Optimization, and techniques of decision and utility theory, are modestly useful so long as they are not believed. The number of variables and non-linearities encountered in resource problems exceeds the capacity of existing techniques. If simplifying assumptions are made, they do provide interesting starting points to direct endeavor. But those very simplifications can arouse justifiable contempt in the mind of the decision maker as he exposes their gross impracticality.

There should not be one model, there should be several, since all models are lies — at best, partial representations of reality. Each provides a different perceptual window. Truth lies at the intersection of conflicting lies. Such models cannot be validated, they can only be invalidated, just as hypotheses can only be disproved. The key therefore is to establish the limits of credibility of the model by putting it at risk. And that can be done in both public and private settings. As a consequence, the analyst must put himself at risk as well, in order to establish his own limits of credibility for his publics.

3. Institutions.

For all its challenges, fun, and value, implementation is agony. For every day of analysis, implementation can require six days of communication, mutual learning, trial-and-error, and inter-

action at all decision and staff levels. Moreover it requires as much creativity and professionalism as does analysis and requires considerably more wisdom and patience.

The effectiveness of implementation is critically dependent on a "wise man" who is an integral part of the institutional environment. His position need not be one of obvious authority, but he must have influence and the respect (even if grudging) of other institutional actors. But those actors are organisms like any other, and, as any good biologist must recognize, have well-developed survival responses. Many of these, legitimately or illegitimately, frustrate innovation and change. Some of the frustration comes from experts, managers or decision people who simply are motivated to continue doing familiar things irrespective of their need or value — to seem to be busy and useful. How many data collection programs and field surveys, for example, are dominated by the desire to measure that which is easily measurable and not that which is important? Some frustrations come from territorial defence. Progress of the budworm study, for example, was profoundly slowed by senior management of the Canadian federal research agency who demanded that sufficient recognition be given to their "contribution" by setting their terms for involvement of the provincial agency. That stopped progress toward implementation for nearly two years.¹⁴ Similarly, agencies attempt to protect negotiating positions. Senior management of a key agency of the State of Nevada refused to participate or have his staff participate in a workshop for fear of revealing data and positions at a time of looming legal conflict involving the Truckee-Carson water problem. Finally, middle management in government and industry often represent a bulge of incompetence that frustrates change within an organization, however much desired above and below. In the words of the Vice-President of a major international mining corporation, "There is a good reason why many middle managers never become senior ones."

Above all, implementation requires patience. It requires time for ideas to gestate, for inter-personal and inter-institutional adjustments to occur. It requires time for key unlocking events to occur — a crisis, an election, a public hearing. Some can be planned, most occur as surprises. At one point the budworm study seemed, at best, to have only changed data collection programs, albeit significantly. All efforts to institute policy change seemed to be frustrated at the eleventh hour. In despair, Baskerville wrote an explicit critique of federal, provincial, and our own activities for the IIASA policy seminar.¹⁴ There were three responses: first, it is not true; second, it is true but we cannot do things differently; third, Baskerville, how would you like a job as Assistant Deputy Minister?

WHERE WE ARE STUMBLING

Life is ever delightfully uncertain and ambiguous: the act of bridging gaps has led to new ones, to new problems. At the moment I can hardly define whether they are important or transient, so they are presented here as potential problems only. Perhaps they will disappear.

1) SOME MODELS HAVE PREDICTED TOO WELL

All work on GIRLS stopped in 1970 and moreover, the model was initialized with data from 1900. And yet the model has tracked, surprisingly well, changes in selling prices, rates of development and rates of environmental decline since 1970. Similarly, the budworm model, in a more qualitative way, accurately predicted radically different behaviors in different regions of North America. That is surprising because we always argued that simulation models were lies, whose quantitative predictions you could not trust and whose usefulness was in giving insight and mediating constructive dialogue. I could argue that the reason for this high predictive power came because we insisted on a process structure that relied on well-tested and carefully generalized representations of those processes. But I am simply not sure. The reason why this is a problem is precisely that. One cannot, a priori, identify the limits of predictive power or robustness, no matter how much effort goes into invalidation. It was much easier when we could automatically disbelieve the results!

2) BEING ADAPTIVE IS ESSENTIAL, BUT ----

There is certainly no doubt that one cannot predict everything, anticipate all surprises. That is why we argue for an adaptive emphasis that allows probing, experimentation, learning and change. But we encounter two problems. The first is that we are living in an unforgiving world that penalizes error, gambling, and hence learning. The very word adaptive has been attacked by elements of the USFWS and the Bureau of Land Management. Some who feel beleaguered in their defence of the environment believe in an all-or-none world, and that an adaptive sequence will lead to a fait accompli for the developer. Give the developer a pilot study and he will take a project!

The second problem with an excessive emphasis on an adaptive approach is that for certain developments the actual costs of experiment error can truly be too large for society to bear. Chemicals that trigger cancer decades later. Nuclear power plants. We can keep trying to develop new designs that are more forgiving of error, but we are stuck with many that demand some kind of predictive screening devices. But what are the rules for stopping the search for bad effects? Search hard enough and practically anything has deleterious consequences. What is the balance between prediction, regulation and adaptation? Swing one way and it is too dangerous, swing the other and it smothers innovation.

3) THE EMBRACE OF IGNORANCE

In many situations we have discovered what seems to be an explicit wish to be ignorant:

- "If I remain ignorant I can't be held culpable." That seems to motivate expensive surveys and the fear of evaluation.

- "If everyone, including me, remains ignorant I have the chance of seeming to be decisive." That seems to be the regulator's dilemma. It has led to the forcing of tertiary water treatment requirements, ostensibly to protect an endangered fish species when the real threat probably relates to spawning and homing questions. But no one wants to find that out because it is easier to force the policy.
- "If I keep others ignorant, then life is easier and I will win." That is a common syndrome for reasons of negotiation, fear of losing control, and protection of power. Every one of our projects has encountered that problem to some degree.
- "If I remain ignorant of others' goals, approaches and insights, I can retain my purity in defence of those values that I cherish." Parochialism and adherence to cherished beliefs are major causes of miscalculation.

4) PUBLIC INVOLVEMENT

The adaptive approach in principle would seem to be tailored for the public. At the minimum it makes assumptions visible, forces unanticipated questions, leads to design of alternatives, and defines the reasons for leaving things out. And it certainly worked having direct involvement of the people of Obergurgl. But the problem is size. Workshops (as distinct from information sessions) can contain only about 25 participants. Perhaps the route is to involve those publics who wish to contribute (from each according to his ability, to each according to his work!). That could lead to management experiments, monitoring and response in which public groups were an integral part of the design and operation. Hardly an easy thing to do in the unforgiving society where, with some reason, some publics have lost their trust. But if it is not attempted as a creative and balanced effort of integration, environmental and resource management will be faced with ever increasing surprises and failures.

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